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Electronic waste and the risks to human and environmental health: a bibliographical review

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Abstract

Background: Electronic waste has a varied composition, and may contain metallic alloys, plastics, composites, ceramic material, glass and oxides. Among the elements with the most significant risk to human health are heavy metals. These elements can contaminate the soil and water resources, reaching the food chain, since they are bio-accumulative, hurting plants, animals and humans. The objective was to discuss the risks inherent to electronic waste for human and environmental health.

Methods: This study was characterized as a descriptive bibliographic review, in which databases were consulted, through the use of descriptors: electronic waste; heavy metals and health. Bibliography sources in Portuguese, English and Spanish were selected, considering mainly the sources from 2015 to 2022. The present study was characterized as bibliographical research, through the literary consultation of previously published material and information in the public domain, dispensing with the need for prior authorization to take an ethics exam.

Results: Regarding human health, heavy metals can lead to acute effects, depending on the dose and exposure time, as well as the long-term effect deadline. An example of heavy metals and human health issues are arsenic (pulmonary and neurological alterations); cadmium (renal and pulmonary alterations); chromium (lung disorders); lead, renal and hepatic alterations); nickel (pulmonary) and mercury (pulmonary and neurological). In the long term, these heavy metals can contribute to the development of cancers in these tissues.

Conclusion: Therefore, policies must be implemented seeking to encourage regularization and training of recyclers, reinsertion of materials into the production chain, reverse logistics and bioremediation of contaminated areas, to reduce environmental impacts and human exposure to heavy metals.

Keywords: Heavy metal; Electronic waste; Health.

Introduction

The technological development associated with the expansion of electronics allowed for a diversification of products with multiple functionalities. On the other hand, the continuous launch of new devices and the stimulus have contributed to the generation of increasing electronic waste (Rocha, 2008; Fragas; Gonzales, 2020). For a better understanding, Fávero Sobrinho et al (p. 1, 2019) conceptualise that: Electronic waste means any discarded or obsolete electrical and electronic material and electrical and electronic material means any equipment that depends on electric current or electromagnetic field to function.

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Electronic waste has a varied composition and may contain metallic alloys, plastics, composites, ceramic material, glass and oxides. Among the elements at the most significant risk to human health are heavy metals (Franco et al., 2021; Reis, 2021). These can be defined, according to Sonone *et al* (p. 2148, 2021). Some of the most common heavy metals in electronic waste are mercury, lead, nickel, chromium, cadmium and arsenic. These elements can contaminate the soil and aquifer resources, reaching the food chain, since they are bio-cumulative, hurting plants, animals and humans (Majid *et al.,* 2019; Ali *et al.,* 2019).

Regarding human health, heavy metals can cause acute effects, depending on the dose and exposure time, as well as long-term effects. Mahurpawar (2015) cites some examples, namely: arsenic (lung and neurological disorders); cadmium (renal and pulmonary alterations); chromium (lung disorders); lead, renal and hepatic alterations); nickel (pulmonary) and mercury (pulmonary and neurological). In the long term, these heavy metals can contribute to the development of cancers in these tissues. In this sense, this article aimed to discuss the importance of electronic waste for human and environmental health.

Methodology

This study was characterized as a descriptive bibliographic review, in which databases were consulted, through the use of descriptors: electronic waste; heavy metals and health. Bibliographical sources in Portuguese, English and Spanish were selected, considering mainly sources from 2015 to 2022.

Ethical considerations

The present study was characterized as bibliographical research, through the literary consultation of previously published material and information in the public domain, dispensing with the need for prior authorization to take an ethics exam.

Review results and discussion

Electronic waste and heavy metal

Electronic waste or electronic equipment waste (WEEE) is the result of waste from the production process and obsolete equipment. Due to some factors such as technological advances, consumerism and planned obsolescence, there is a growing disposal of these materials, including cell phones, computers, printers, hair dryers, refrigerators, air conditioners, refrigerators, stoves and remote controls, which have a cycle lower repair option (Majid *et al.,* 2019; Forti; 2020; Salam & Varma. 2019). These residues have a varied composition, from precious metals such as silver or gold; to highly toxic metals such as mercury, lead, nickel, chromium, cadmium and arsenic. Furthermore, you can find; brominated flame retardant materials, chlorofluorocarbons, hydrochlorofluorocarbons, glass and different types of plastics (Rocha, 2008; Majid *et al,* 2019; Salam & Varma, 2019; Tanau *et al,* 2015).

Due to the prominent growth of WEEE and the various impacts they cause on the Environment, there is a need to determine which processes are required to achieve the 3 R (Reuse, Recycling and Reduction) taking into account the durability of components/equipment of this nature (Martins, 2020) in risks to environmental health (fauna and flora) and human health. In addition, there is a loss of economic potential, since these materials could be sent for recycling, contributing to the reduction of the use of raw materials, reuse of precious materials and the possibility of generating employment in recycling companies (Tanau *et al.,* 2015). From an environmental point of view, one of the biggest problems associated with REEs refers to the release of heavy metals into the environment, which is bioaccumulative, toxic and potentially carcinogenic.

Heavy metals

Heavy metals represent a wide range of chemical elements that are bioaccumulative, capable of increasing their concentration through the food chain, thus potentiating their toxic effects on living beings at the top of the chain, such as man (Mahurpawar, 2015). Rocha (p. 21, 2008) defines heavy metals as:

A group of elements located between Copper (Cu) and Lead (Pb) on the periodic table. These metals are chemically very reactive and bioaccumulative, that is, the body is not able to eliminate them quickly and effectively.

Heavy metals are part of countless products and materials used today, among them are agriculture with its pesticides, metal alloys, batteries, paints, electronics and paints. Some metallic elements are important in a certain amount and are indispensable to the biological system such as Iron (Fe), Zinc (Zn), Copper (Cu) and Manganese (Mn), while others such as Nickel (Ni) are necessary for plants. However, even if necessary, the excess amount of these metals in the environment leads to soil, water and air contamination and can lead to harmful effects on environmental and human health (Majid *et al.,* 2019; Tanaue *et al.,* 2015).

Table 01: illustrates some of the chemical elements present in electronic waste, as well as the route and form of potential exposure, in which man can be exposed to heavy metals. These facts, associated with exposure time and contact dosage, may influence the toxic effects of heavy metals on humans (Perkins *et al.,* 2014).

Table 01: Potential risk of exposure to heavy metals present in REEs

Heavy metal	Electric/electronic component	Exposure route	Form of exposure
Lead	Cathode tubes, televisions and batteries	Particles, water, soil and air	Skin contact Inhalation ingestion
Chromium and cadmium	Chips, batteries, semiconductors, cell phones, remote controls	Particles, water, soil and air	Inhalation Ingestion
Mercury	Thermometers, sensors, lamps, circuits	Particles, vapours, water, soil and air	Skin contact Inhalation ingestion
Nickel and zinc	Batteries, cathodes, chips	Water, soil and air	Skin contact Inhalation Ingestion
Arsenic	Cell phones	Water, soil and air	Inhalation ingestion
Aluminum	Cell phones, metal alloys, printers, televisions	Water, soil and air	Inhalation Ingestion
Silver	Circuits	Water, soil and air	Inhalation ingestion
Iron	Printers, televisions, printers	Water, soil and air	Inhalation ingestion

Source: Adapted from Perkins *et al* (2014).

Risks to human health

WEEE is commonly disposed of improperly, most of which are discarded in dumps and even in landfills. When discarded in the environment, electronic waste ends up exposed to the weather or burned, favouring the release into the environment of chemical elements harmful to humans, such as heavy metals (Tanaue *et al.,* 2015). Toxicity is the major cause of concern related to contamination by heavy metals, as it is the inherent ability of a chemical agent to produce damage to living organisms, being equivalent to a poison, it causes a disturbance to organic elements and

may be irreversible. The metal can accumulate in soft tissues when absorbed through ingestion of contaminated food and water or entering the body through the air and skin, the human body concerns can occur in the brain, kidneys, lungs, liver, blood and other important organs. Many of these metallic elements are carcinogenic, and the period of contact and the quantity allow a division between acute and chronic intoxication (Rocha, 2008; Devin, 2014; Majiid *et al.,* 2019). Table 2 mentions some diseases caused by the toxicity of some heavy metals, which may lead to acute or chronic physiological changes, with risks of carcinogenesis (Tanaue *et al.,* 2015; Majiid *et al.,* 2019).

Table 2. Heavy metals and their main effects on the body

Metal	Symbol	Atomic number	Some health achievements
Magnesium	Mg	12	It may cause cardiac arrest, loss of kidney function, mental confusion and difficulty breathing
Aluminum	Al	13	May cause dementia, personality change, seizures, coma and cancer
Manganese	Mn	25	May cause a mental and emotional disturbance, slower and uncoordinated body movements
Iron	Fe	26	May cause blood clotting disorders and digestive system cancer
Nickel	Ni	28	May cause pulmonary oedema, pneumonia, breathing problems and cancer
Copper	Cu	29	May cause liver failure, Wilson's disease, gastrointestinal bleeding
Zinc	Zn	30	May cause anaemia, increased LDL, decreased HDL, and lymphocyte alteration
Arsenic	As	33	It can cause skin diseases, affect the nervous and vascular systems and cause cancer.
Silver	Ag	47	May cause bone marrow failure, skin pigmentation and coma
Cadmium	Cd	48	It can cause damage to bones, kidneys, and lungs and affects the nervous and respiratory systems.
Mercury	Hg	80	May cause brain damage, liver damage, kidney necrosis quick death
Lead	Pb	82	May cause nervous, blood, and digestive system damage and cancer

Source: Adapted from Brigeden *et al* (2020); Lozi (2019), Tanaue *et al* (2015).

Environmental contamination by heavy metals from electronic waste has occurred mainly in developing countries like Brazil, this is mainly due to inadequate disposal and inappropriate recycling, where components are abandoned in the open, contaminating soil, water, crops and humans (Wu *et al.,* 2015). In the literature, several situations of contamination by heavy metals resulting from WEEE are pointed out, as observed by Wu *et al* (2015) in China, in which they mentioned the contamination of soil, water and rice fields by cadmium and copper, close to a recycling area/ disposal of this waste.

In turn, Jiang *et al* (2019) pointed out the change in soil microbiota in Nigeria, due to cadmium and chromium metals. The authors explain that heavy metals compete with other bacterial micronutrients, affecting their enzymatic system, thus reducing their metabolism and their role in the geological cycle, such as the degradation of local organic matter. From soil and water contamination, heavy metals can be absorbed by plants and reach animals that serve as food for humans. Thus, they can lead to serious risks to human health, as explained by Zeng *et al* (2016), who point out the risks to the health of fetuses and children when exposed to heavy metals,

including low lung function and immunity, hepatitis, hyperactivity, chromosomal and bone alterations. These conditions can result in consequences for the entire life of the individual.

Given environmental and health issues, policies and programs aimed at the proper management of WEEE should be implemented, especially in small towns, favouring the collection of these materials, recycling and reverse logistics. This will contribute to the reinsertion of materials into the production chain, regularization and training of recyclers, income generation and reduction of inappropriately discarded material. The mapping of clandestine and contaminated areas must be carried out, so that bioremediation studies can be implemented, seeking their decontamination (Brito *et al*., 2021). Furthermore, as these are long-term effects, public health costs could be reduced in the future, as a result of the reduction in illnesses associated with exposure to heavy metals released into the environment.

Conclusion

Electronic waste is a problem to be managed in most of Brazil, since most of it is disposed of improperly, resulting in environmental risks and human health. The population lacks environmental education and awareness of the correct way to dispose of WEEE, as well as the nearest collection points in their city or state. This implies risks of contamination of soil, water and plantations by heavy metals that can compromise several human physiological systems (nervous, hepatic, renal, bone and hematopoietic), in addition to the risk of carcinogenesis. Therefore, policies must be implemented seeking to encourage the regularization and training of recyclers, reinsertion of materials into the production chain, reverse logistics and bioremediation of contaminated areas, to reduce environmental impacts and human exposure to heavy metals.

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